Science Skills

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Concept 1 Science Skills

Lesson Objectives

- Explain how measurements are made in scientific research.
- Describe how to keep good records in scientific investigations.
- Demonstrate how to use significant figures and scientific notation.
- Calculate descriptive statistics and use data graphs.
- Identify the role of models in science.
- Describe how to stay safe when doing scientific research.

Lesson Vocabulary

- accuracy
- Kelvin scale
- mean
- model
- precision
- range
- scientific notation
- SI
- significant figures

Introduction

Measuring is an important science skill. Other skills needed to do science include keeping records, doing calculations, organizing data, and making models. Knowing how to stay safe while doing scientific investigations may be the most important skill of all. You will read about all these science skills in this lesson.

Measuring

One of the most important aspects of measuring is the system of units used for measurement. Remember the Mars Climate Orbiter that opened this chapter? It shows clearly why a single system of measurement units is needed in science.

Using SI Units

The measurement system used by most scientists is the International System of Units, or **SI**. **Table** 1.1 lists common units in this system. SI is easy to use because everything is based on the number 10. Basic units are multiplied or divided by powers of ten to arrive at bigger or smaller units. Prefixes are added to the names of the basic units to

indicate the powers of ten. For example, the meter is the basic unit of length. The prefix *kilo-* means 1000, so a kilometer is 1000 meters. Can you infer what the other prefixes in the table mean? If not, you can find out at this URL: http://physics.nist.gov/cuu/Units/prefixes.html.

TABLE 1.1: Common SI Units

Variable	Basic SI Unit (English Equivalent)	Related SI Units	Equivalent Units
Length	meter (m)	kilometer (km)	= 1000 m
	(1 m = 39.37 in)	decimeter (dm)	= 0.1 m
		centimeter (cm)	= 0.01 m
		millimeter (mm)	= 0.001 m
		micrometer (μm)	= 0.000001 m
		nanometer (nm)	= 0.000000001 m
Volume	cubic meter (m^3)	liter (L)	= 1 dm^3
	(1 m^3 = 1.3 yd^3)	milliliter (mL)	= 1 cm^3
Mass	gram (g)	kilogram (kg)	= 1000 g
	(1 g = 0.04 oz)	milligram (mg)	= 0.001 g

The SI system has units for other variables in addition to the three shown here in **Table** 1.1. Some of these other units are introduced in later chapters.

Problem Solving

Problem: Use information in **Table** 1.1 to convert 3 meters to inches.

Solution: $3 \text{ m} = 3 \times 39.37 \text{ in} = 118.11 \text{ in}$

You Try It!

Problem: Rod needs to buy 1 m of wire for a science experiment. The wire is sold by the yard, not the meter. If he buys 1 yd of wire, will he have enough? (*Hint*: How many inches are there in 1 yd? In 1 m?)

Measuring Temperature

The SI scale for measuring temperature is the **Kelvin scale**. However, some scientists use the Celsius scale instead. If you live in the U.S., you are probably more familiar with the Fahrenheit scale. **Table** 1.2 compares all three temperature scales. What is the difference between the boiling and freezing points of water on each of these scales?

TABLE 1.2: Temperature Scales

Scale	Freezing Point of Water	Boiling Point of Water
Kelvin	273 K	373 K
Celsius	0°C	100°C
Fahrenheit	32°F	212°F

Each 1-degree change on the Kelvin scale is equal to a 1-degree change on the Celsius scale. This makes it easy to convert measurements between Kelvin and Celsius. For example, to go from Celsius to Kelvin, just add 273. How would you convert a temperature from Kelvin to Celsius?

Converting between Celsius and Fahrenheit is more complicated. The following conversion factors are used:

- $\textit{Celsius} \rightarrow \textit{Fahrenheit}: \ (^\circ\text{C} \times 1.8) + 32 = \ ^\circ\text{F}$
- $\textit{Fahrenheit} \rightarrow \textit{Celsius}: \ (^\circ\text{F} - 32) \div 1.8 = \ ^\circ\text{C}$

Problem Solving

Problem: Convert 10°C to Fahrenheit.

Solution: $(10°\text{C} \times 1.8) + 32 = 50°\text{F}$

You Try It!

Problem: The weather forecaster predicts a high temperature today of 86°F. What will the temperature be in Celsius?

Using Measuring Devices

Measuring devices must be used correctly to get accurate measurements. **Figure** 1.1 shows the correct way to use a graduated cylinder to measure the volume of a liquid.

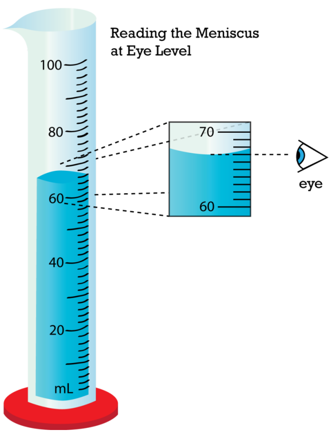


FIGURE 1.1
This cylinder contains about 66 mL of liquid. What would the measurement be if you read the top of the meniscus by mistake?

Follow these steps when using a graduated cylinder to measure liquids:

- Place the cylinder on a level surface before adding liquid.
- Move so your eyes are at the same level as the top of the liquid in the cylinder.
- Read the mark on the glass that is at the lowest point of the curved surface of the liquid. This is called the meniscus.

At the URLs below, you can see the correct way to use a metric ruler to measure length and a beam balance to measure mass.

- http://www.wsd1.org/waec/math/Consumer%20Math%20Advanced/Unit%202%20Design%20and%20Measurement/Ruler%20Meas/measmain.htm (metric ruler)
- http://www.youtube.com/watch?v=C9howXG7LUY&feature=related (beam balance) (5:14)

MEDIA
Click image to the left for more content.

Accuracy and Precision

Measurements should be both accurate and precise.

- **Accuracy** is how close a measurement is to the true value. For example, 66 mL is a fairly accurate measurement of the liquid in **Figure** 1.1.
- **Precision** is how exact a measurement is. A measurement of 65.5 mL is more precise than a measurement of 66 mL. But in **Figure** 1.1, it is not as accurate.

You can think of accuracy and precision in terms of a game like darts. If you are aiming for the bull's-eye and get all of the darts close to it, you are being both accurate and precise. If you get the darts all close to each other somewhere else on the board, you are precise, but not accurate. And finally, if you get the darts spread out all over the board, you are neither accurate nor precise.

Keeping Records

Record keeping is very important in scientific investigations. Follow the tips below to keep good science records.

- Use a bound laboratory notebook so pages will not be lost. Write in ink for a permanent record.
- Record the steps of all procedures.
- Record all measurements and observations.
- Use drawings as needed.
- Date all entries, including drawings.

Calculating

Doing science often requires calculations. Converting units is just one example. Calculations are also needed to find derived quantities.

Calculating Derived Quantities

Derived quantities are quantities that are calculated from two or more different measurements. Examples include area and volume. It's easy to calculate these quantities for a simple shape. For a rectangular solid, like the one in **Figure** 1.2, the formulas are:

$$\text{Area (of each side)} = \text{length} \times \text{ width } (l \times w)$$
$$\text{Volume} = \text{length} \times \text{width} \times \text{height } (l \times w \times h)$$

Helpful Hints

When calculating area and volume, make sure that:

- all the measurements have the same units.
- answers have the correct units. Area should be in squared units, such as cm^2; volume should be in cubed units, such as cm^3. Can you explain why?

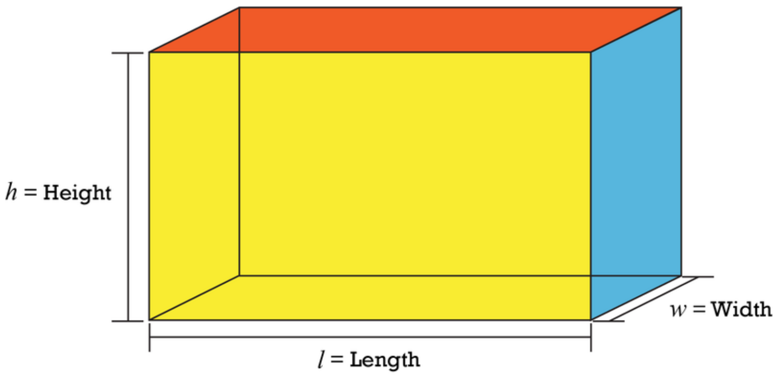


FIGURE 1.2
Dimensions of a rectangular solid include length (l), width (w), and height (h). The solid has six sides. How would you calculate the total surface area of the solid?

Naturally, not all derived quantities will have the same types of units. In the examples above, the only fundamental unit used was meters for the length of one of the sides of the box. However, if you had a quantity like speed (a derived quantity), it would be equal to distance traveled (which is meters) divided by the amount of time you spent traveling that distance (which is in seconds). Therefore your speed would be measured in meters per second.

Using Significant Figures

Assume you are finding the area of a rectangle with a length of 6.8 m and a width of 6.9 m. When you multiply the length by the width on your calculator, the answer you get is 46.92 m^2. Is this the correct answer? No; the correct answer is 46.9 m^2. The correct answer must be rounded down so there is just one digit to the right of the decimal point. That's because the answer cannot have more digits to the right of the decimal point than any of the original measurements. Using extra digits implies a greater degree of precision than actually exists. The correct number of digits is called the number of **significant figures**. To learn more about significant figures and rounding, you can watch the videos at the URLs below.

- http://www.youtube.com/watch?v=ZbTxK6-1fDg (3:20)
- http://www.youtube.com/watch?v=MuVyoqz5lxM&feature=related (8:30)

Using Scientific Notation

Quantities in science may be very large or very small. This usually requires many zeroes to the left or right of the decimal point. Such numbers can be hard to read and write accurately. That's where scientific notation comes in. **Scientific notation** is a way of writing very large or small numbers that uses exponents. Numbers are written in this format:

$$a \times 10^b$$

The letter *a* stands for a decimal number. The letter *b* stands for an exponent, or power, of 10. For example, the number 300 is written as 3.0×10^2. The number 0.03 is written as 3.0×10^{-2}. **Figure** 1.3 explains how to convert numbers to and from scientific notation. For a review of exponents, watch: http://www.youtube.com/watch?v=8htcZca0JIA.

You Try It!

Problem: Write the number 46,000,000 in scientific notation.

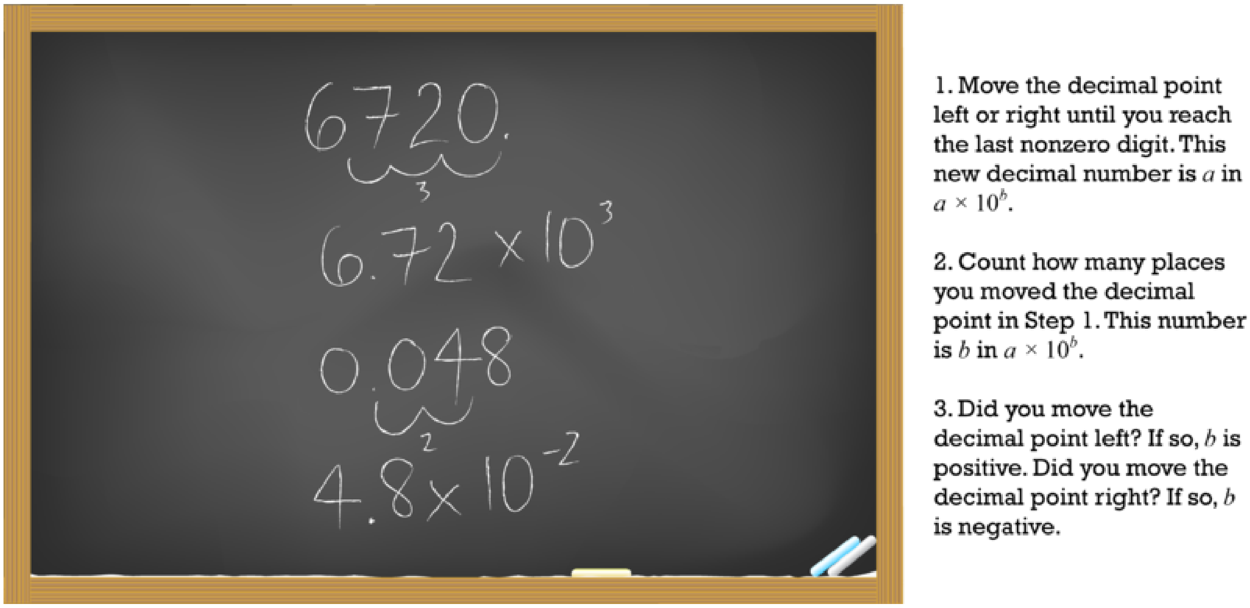


FIGURE 1.3
Follow the steps in reverse to convert numbers from scientific notation.

Organizing Data

In a scientific investigation, a researcher may make and record many measurements. These may be compiled in spreadsheets or data tables. In this form, it may be hard to see patterns or trends in the data. Descriptive statistics and graphs can help organize the data so patterns and trends are easier to spot.

Example: A vehicle checkpoint was set up on a busy street. The number of vehicles of each type that passed by the checkpoint in one hour was counted and recorded in **Table** 1.3. These are the only types of vehicles that passed the checkpoint during this period.

TABLE 1.3: **Data Table**

Type of Vehicle	Number
4-door cars	150
2-door cars	50
SUVs	80
vans	50
pick-up trucks	70

Descriptive Statistics

A descriptive statistic sums up a set of data in a single number. Examples include the mean and range.

- The **mean** is the average value. It gives you an idea of the typical measurement. The mean is calculated by summing the individual measurements and dividing the total by the number of measurements. For the data in **Table** 1.3, the mean number of vehicles by type is: $(150+50+80+50+70) \div 5 = 80$ (There are two other words people can sometimes use when they use the word "average." They might be referring to a quantity called the "median" or the "mode." You'll see these quantities in later courses, but for now, we'll just say the average is the same thing as the mean.)

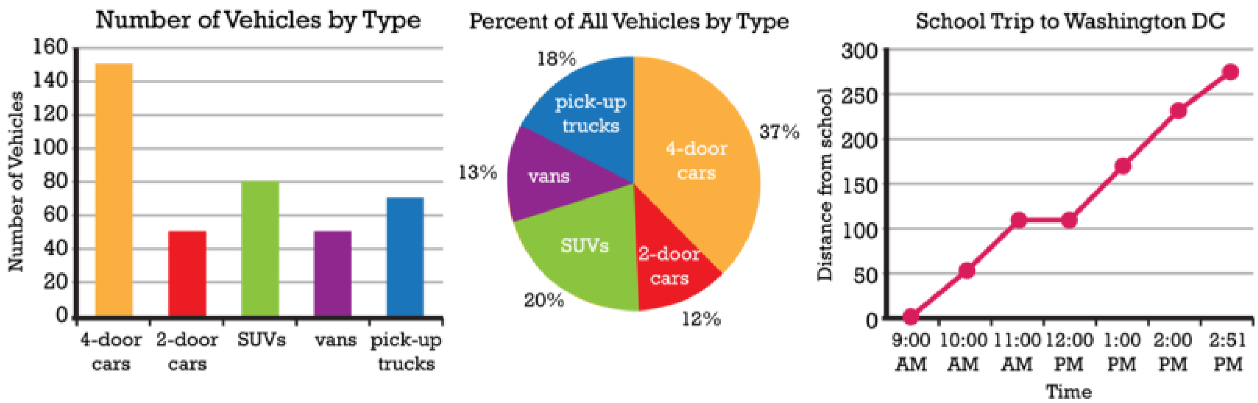


FIGURE 1.4
These are three commonly used types of graphs. When would you want to use a bar graph? What about a line graph?

- Percents are fractions in which the denominator is 100. *Example:* 30% = 30/100
- Percents can also be expressed as decimal numbers. *Example:* 30% = 0.30

You Try It!

Problem: Show how to calculate the percents in the circle graph in **Figure** 1.4.

Need a refresher on percents, fractions, and decimals? Go to this URL: http://www.mathsisfun.com/decimal-fraction-percentage.html.

Using Models

Did you ever read a road map, sketch an object, or play with toy trucks or dolls? No doubt, the answer is yes. What do all these activities have in common? They all involve models. A **model** is a representation of an object, system, or process. For example, a road map is a representation of an actual system of roads on the ground.

Models are very useful in science. They provide a way to investigate things that are too small, large, complex, or distant to investigate directly. **Figure** 1.5 shows an example of a model in chemistry. To be useful, a model must closely represent the real thing in important ways, but it must be simpler and easier to manipulate than the real thing. Do you think the model in **Figure** 1.5 meets these criteria?

Staying Safe in Science

Research in physical science can be exciting, but it also has potential dangers. Whether in the lab or in the field, knowing how to stay safe is important.

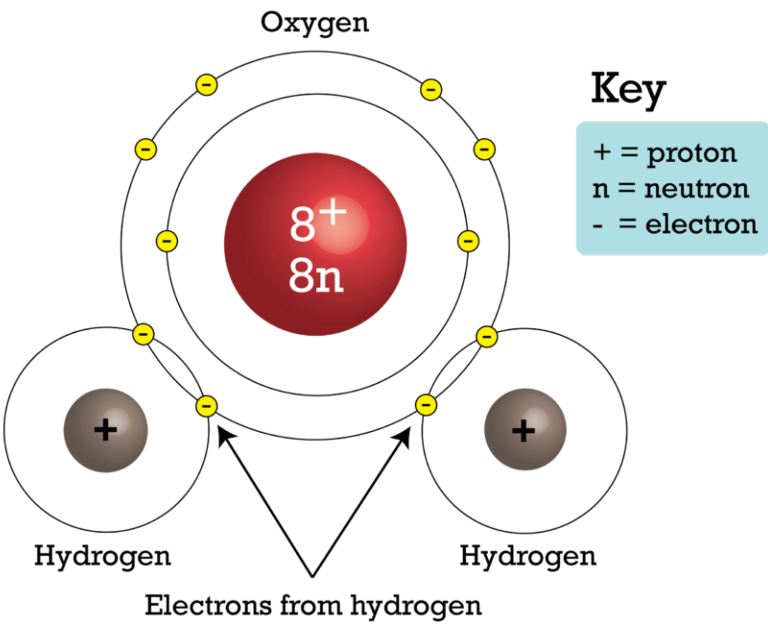


FIGURE 1.5
This model represents a water molecule. It shows that a water molecule consists of an atom of oxygen and two atoms of hydrogen. What else does the model show?

Safety Symbols

Lab procedures and equipment may be labeled with safety symbols. These symbols warn of specific hazards, such as flames or broken glass. Learn the symbols so you will recognize the dangers. A list of common safety symbols is shown in **Figure** 1.6. Do you know how to avoid each hazard? You can learn more at this URL: http://www.angelfire.com/va3/chemclass/safety.html.

FIGURE 1.6
Why does glassware pose a hazard?

Safety Rules

Following basic safety rules is the best way to stay safe in science. Safe practices help prevent accidents. Several lab safety rules are listed below. Different rules may apply when you work in the field. But in all cases, you should always follow your teacher's instructions.

Lab Safety Rules

- Wear safety gear, including goggles, an apron, and gloves.
- Wear a long-sleeved shirt and shoes that completely cover your feet.
- Tie back your hair if it is long.
- Do not eat or drink in the lab.
- Never work alone.
- Never perform unauthorized experiments.
- Never point the open end of a test tube at yourself or another person.
- Always add acid to water — never water to acid — and add the acid slowly.
- To smell a substance, use your hand to fan vapors toward your nose rather than smell it directly. This is demonstrated in **Figure** 1.7.
- When disposing of liquids in the sink, flush them down the drain with lots of water.
- Wash glassware and counters when you finish your lab work.
- Thoroughly wash your hands with soap and water before leaving the lab.

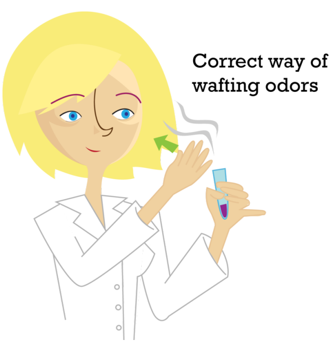


FIGURE 1.7
This is the correct way to smell a chemical in science lab. This helps prevent possible injury from toxic fumes.

Even when you follow the rules, accidents can happen. Immediately alert your teacher if an accident occurs. Report all accidents, even if you don't think they are serious.

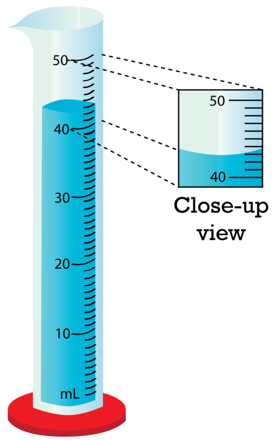
Lesson Summary

- Most scientists use the SI system of units. It includes the Kelvin scale for temperature. Measurements should be both accurate and precise.
- Good record keeping is very important in scientific research.
- Doing science often requires calculations, such as finding derived quantities. Calculations may involve significant figures or scientific notation.
- Descriptive statistics and graphs help organize data so patterns and trends are more apparent. Descriptive statistics include the mean and range. Types of graphs include bar, circle, and line graphs.
- A model is a representation of an object, system, or process. Models help scientists investigate things that are too small, large, complex, or distant to study directly.
- Staying safe while doing scientific research means recognizing safety symbols and following safety rules.

Lesson Review Questions

Recall

1. What are the basic SI units for length, volume, and mass?
2. How much liquid does this graduated cylinder contain?



3. Define the mean and range of a data set. How are they calculated?
4. What is a model? How are models used in science?
5. What hazard does each of these symbols represent?



Apply Concepts

6. Do the following calculations:
   a. Write the number 0.0000087 in scientific notation.
   b. Convert 50°C to °F.
   c. Find the volume of a cube that measures 5 cm on each dimension (length, width, and height).
7. Make a safety poster to convey one of the lab safety rules in this lesson.

Think Critically

8. Compare and contrast accuracy and precision of measurements in science.

Points to Consider

Most of the skills described in this lesson are important in technology as well as science.

- What is technology?
- How do you think technology differs from science?